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Effects of physical exercise training in the workplace on physical fitness: a systematic review and meta-analysis

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ABSTRACT

Background

There is evidence that physical exercise training (PET) conducted at the workplace is effective in improving physical fitness and thus health. However, there is no current systematic review available that provides high-level evidence regarding the effects of PET on physical fitness in the workforce.

Objectives

To quantify sex-, age-, and occupation type-specific effects of PET on physical fitness and to characterize dose-response relationships of PET modalities that could maximize gains in physical fitness in the working population.

Data sources

A computerized systematic literature search was conducted in the databases PubMed and Cochrane Library (2000-2019) to identify articles related to PET in workers.

Study eligibility criteria

Only randomized controlled trials with a passive control group were included if they investigated the effects of PET programs in workers and tested at least one fitness measure.

Study appraisal and synthesis methods

Weighted mean standardised mean differences (SMD_{wm}) were calculated using random effects models. A multivariate random effects meta-regression was computed to explain the influence of key training modalities (e.g., training frequency, session duration, intensity) on the effectiveness of PET on measures of physical fitness. Further, subgroup univariate analyses were computed for each training modality. Additionally, methodological quality of the included studies was rated with the help of the Physiotherapy Evidence Database (PEDro)Scale.

Results

Overall, 3,423 workers aged 30-56 years participated in 17 studies (19 articles) that were eligible for inclusion. Methodological quality of the included studies was moderate with a median PEDro score of 6. Our analyses revealed significant, small-sized effects of PET on cardiorespiratory fitness (CRF), muscular endurance, and muscle power ($0.29 \leq SMD_{wm} \leq 0.48$). Medium effects were found for CRF and muscular endurance in younger workers (≤45 years) ($SMD_{wm}=0.71$) and white-collar workers ($SMD_{wm}=0.60$), respectively. Multivariate random effects meta-regression for CRF revealed that none of the examined training modalities predicted the effects of PET on CRF ($R^2=0$). Independently computed subgroup analyses showed significant PET effects on CRF when conducted for 9-12 weeks ($SMD_{wm}=0.31$) and for 17-20 weeks ($SMD_{wm}=0.74$).

Conclusions

PET effects on physical fitness in healthy workers are moderated by age (CRF) and occupation type (muscular endurance). Further, independently computed subgroup analyses indicated that the training period of the PET programs may play an important role in improving CRF in workers.

KEY POINTS

- Physical exercise training conducted at the workplace significantly improved cardiorespiratory fitness, muscular endurance, and muscle power in the working population.
- The effects of physical exercise training at the workplace were moderated by age and occupation type. Only young workers showed training-induced gains in cardiorespiratory fitness. Increments in muscular endurance were found in white-collar workers only.
- Our dose-response relationships revealed that the examined key training modalities (e.g., training period, training frequency) did not predict the effects of physical exercise training on cardiorespiratory fitness. However, independently computed subgroup analyses indicated that training periods of 17-20 weeks showed the largest effects of physical exercise training on cardiorespiratory fitness.

1. INTRODUCTION

Previous studies have reported a significant relationship between physical fitness and work performance, health, daily life activities, and mobility [1–3]. In general, physical fitness is defined as a set of health- or skill-related attributes (e.g., cardiorespiratory fitness [CRF], muscle strength, balance) that people have or achieve to carry out daily tasks [4]. Higher levels of physical fitness as indicated by upper- and lower-body strength are associated with a lower risk of all-cause mortality in adults across the lifespan [5]. Further, Christensen et al. [6] examined associations between changes in physical fitness and on-the-job performance following three months of a multifactorial intervention program in healthcare workers. The authors reported significant and medium-sized correlations between increments in trunk flexor/extensor strength and gains in on-the-job performance ($.411 \leq$ Pearson's $r \leq .456$), indicating the importance of physical fitness for the working population (i.e., workforce).

In order to improve or maintain physical fitness in adults and seniors, current international physical activity recommendations suggest a minimum dosage of at least 150 min/week of moderate-to-vigorous intensity [7–9]. Physical activity comprises any physical movements produced by skeletal muscles that results in energy expenditure [4]. Interestingly, it was recently highlighted that not all physical activities contribute to fitness and health [10–12]. Occupational physical activities such as lifting heavy loads, repetitive and fatiguing movements, or constrained postures may induce pain and discomfort, thereby decreasing physical fitness [10]. Further, physically demanding work tends to increase the risk for long-term sickness absence and early mortality especially in males, even after adjustment for relevant confounders such as leisure time physical activity, alcohol intake and/or smoking [11, 12]. Thus, it was suggested to regularly include well-structured health-enhancing physical exercises into weekly routines at the workplace to counteract the negative side effects of monotonous physical tasks at work [1, 10]. Further, given that most adults spend half of their waking hours at the workplace, the worksite setting offers a unique opportunity to promote physical activity and fitness as well as engage individuals who might not otherwise participate in physical exercise training.

So far, the literature on the effects of physical exercise training (PET) conducted at the workplace on physical fitness is controversial [13]. According to Caspersen et al. [4] and Garber et al. [7], PET refers to any planned, structured, and repetitive physical activity with the goal to maintain or improve physical fitness and/or health. Methodological limitations (e.g., randomization, blinding, poor compliance) accounted for the many inconsistencies. Since 2003, high-quality randomized and controlled trials (RCTs) have demonstrated that workers' physical fitness can benefit from PET programs [14, 15], making a fresh review of the topic relevant. For example, an 8-week combined balance and strength training compared with a passive control group significantly improved muscle strength, power, and balance in middle-aged workers [14]. One year combined strength and endurance training compared with passive controls significantly enhanced CRF in office workers [15].

To the best of our knowledge, there is currently no systematic review and meta-analysis available that included RCTs only and thus provides the highest level on the evidence-based medicine pyramid regarding the effects of PET on physical fitness (e.g., CRF, muscle strength, balance) in the workforce [16, 17]. Additionally, there is scarce information on how to optimize training effects on physical fitness measures and to avoid over- or under-prescription of PET.

Thus, in an exploratory approach, the objectives of this systematic literature review and meta-analysis were to i) analyse the effects of PET on physical fitness measures in the workforce including potentially modify-ing variables such as age, sex, and type of occupation, and ii) characterize dose-response relationships of PET parameters (e.g., training period, session duration, frequency, intensity) by quantitative analyses of PET studies in workers. We hypothesized that i) PET has a beneficial effect on physical fitness in the workforce, and ii) the effects are moderated by age, sex, and type of occupation.

2. METHODS

Our systematic literature review was conducted in accordance with the recommendations of the ''Preferred Reporting Items for Systematic Reviews and Meta-Analyses'' (PRISMA) [18].

2.1. Literature search

We performed a computerized systematic literature review in the electronic databases PubMed and Cochrane Library from 01/01/2000 to 30/06/2019. A Boolean-search strategy was used with the operators "AND", "NOT" and "OR" as well as study keywords related to physical fitness, PET, and workers (Table S1). The search was limited to ages (18-65 years) and languages (English, German). Further, the reference lists of the included studies and relevant review articles [1, 10, 13, 19] were screened for titles to identify additional adequate references for inclusion in our meta-analysis.

2.2. Eligibility criteria for selecting studies

Studies were included in this systematic review and meta-analysis if they provided relevant information with regards to the PICOS approach (i.e., participants, interventions, comparators, outcomes, and study design) [18]. The following criteria were predefined for inclusion: (a) full-text availability; (b) population: workers with mean ages ranging from 18 to 65 years; (c) intervention: PET programs for the promotion of physical activity/fitness (e.g., cardiovascular training, strength training, team sport activities) performed at or nearby the workplace; (d) comparator: passive control group (i.e., no alternative training) maintaining its regular activity behaviour; (e) outcome: at least one measure of CRF, muscle strength, muscular endurance, muscle power, and/or balance; (f) study design: RCT.

Studies were excluded if they: (a) specifically included patient populations only (e.g., hypertension, type 2 diabetes); (b) had no control group or alternative intervention groups (e.g., behavioural training) only; (c) did not meet the minimum requirements regarding the description of at least one training modality (e.g., training duration, frequency, or intensity); (d) did not report results adequately (i.e., means and standard deviations/errors) or if respective authors did not reply to our inquiries sent by email. Based on the a priori defined inclusion and exclusion criteria, two independent reviewers (OP, MH) screened potentially relevant articles by analysing titles, abstracts, and full texts of the respective articles to elucidate their eligibility. In case MH and OP did not reach an agreement concerning the inclusion of an article, a third author (UG or TD) was contacted.

2.3. Coding of studies

All included studies were coded for the variables listed in Table 1. A template from previous systematic reviews and meta analyses of our research group was used to extract data [20, 21]. One author (MH) extracted the data from the included studies and a second author (OP) double-checked the extracted data. Disagreements were resolved through personal communication between the two authors (MH, OP). If no agreement was achieved, a third author was contacted (TD) to solve previous disagreement. Our analyses focused on different measures of physical fitness. If studies reported multiple variables within one of these fitness components, only one representative outcome variable was included in the analyses. The variable with the highest priority for each outcome was illustrated in Table 1. If studies reported outcome variables other than the preferred variables, we included test variables that were most similar to the ones described above in terms of their temporal/ spatial structure.

Further, we coded PET according to the following training parameters: training type (e.g., resistance training, endurance training), training period, frequency (i.e., sessions/week), session duration, intensity, and supervision (i.e., supervised, less supervised). If a study reported exercise progression over the training period, the mean number of frequency and session duration were computed. PET was defined as supervised if at least 50% of the sessions were attended by an instructor supervising the execution of exercises [22]. Accordingly, a training group was rated as less supervised, if less than 50% of the sessions were attended by an instructor. To obtain sufficient statistical power to calculate dose-response relationships, we computed our analyses irrespective of age, sex, and type of occupation.

2.4. Assessment of risk of bias

The Physiotherapy Evidence Database (PEDro) scale was used to quantify the risk of bias in eligible studies and to provide information on the general methodological quality of studies. The PEDro scale rates internal study validity and the presence of statistical replicable information on a scale from zero (high risk of bias) to ten (low risk of bias) with ≥6 representing a cut-off score for studies with low risk of bias [23]. In this regard, it has to be taken into account that it is impossible to blind participants and instructors in PET studies as rated by the PEDro scale. If available, one author of our research group (MH) obtained information on the PEDro scores of the respective studies from the PEDro database (www.pedro.org.au). If studies were not listed in the database, one author (MH) evaluated the respective studies according to the eleven items of the PEDro scale and a second author (OP) double-checked the scores.

2.5. Statistical analysis

To determine the effects of PET on physical fitness measures in the workforce, the between-subject standardized mean differences (SMD) were calculated according to the following equation: $SMD = \frac{m_1 - m_2}{s_{pooled}}$ where m_1 stands for the mean post-value of the PET group, m_2 for the mean post-value of the control group, and s_{pooled} for the pooled standard deviation. Whenever possible, data from intention-to-treat analyses were used. In accordance with Hedges and Olkin [24], the SMD was adjusted for the respective sample size by using the factor $\left(1 - \frac{3}{4N-9}\right)$ with N representing the total sample size. A random effects model was applied to weight each included articles according to the magnitude of the respective standard error and to finally calculate the weighted mean SMD (SMD_{wm}). SMD_{wm} were aggregated for the respective outcomes if the training type was specific for the outcome (e.g., endurance training, team sports, and multicomponent training for CRF). Subgroup univariate analyses for moderator variables (i.e., sex, age, type of occupation) were computed by aggregating SMD_{wm} values for specific subgroups by comparing subgroup effect sizes for statistically significant differences using a Chi^2 trend test. To specify dose–response relationships, additional subgroup univariate analyses were calculated for program modalities (i.e., training type, training period, frequency, session duration, intensity, supervision). Additionally, multivariate random effects meta-regressions were computed with Comprehensive Meta-analysis version 3.3.07 (Biostat Inc., Englewood, NJ, USA) to verify if any of the examined program modalities predict the effectiveness of PET in the workforce. At least two PET intervention groups had to be included to calculate SMDs, for each proxy of physical fitness [25]. This meta-analysis was conducted using Review Manager 5.3 (Nordic Cochrane Centre, Copenhagen, Denmark). Positive SMD values were consistently reported if the effects were in favour of PET compared with a control. For data interpretation, effect size values of $SMD < 0.50$ indicate small, of $0.50 \leq SMD < 0.80$ indicate medium, and of $SMD \geq 0.80$ indicate large effects [26]. Further, between-study heterogeneity was assessed using I^2 and Chi^2 statistics. Heterogeneity was interpreted as low ($I^2 \leq 25\%$), moderate ($25\% < I^2 \leq 50\%$), high ($50\% < I^2 \leq 75\%$), or considerable ($I^2 > 75\%$) [27, 28]. The level of significance was set at $p < .05$.

3. RESULTS

3.1. Study characteristics

A total of 515 potentially relevant articles were identified by the searches (Figure 1). Finally, 17 studies (19 articles; n = 3,423 workers at baseline; 1,065 men, 2,358 women) remained for the quantitative analysis. The sample size in the individual studies ranged from 19-730 participants (Table 2). There were 2 studies that included males only, 3 studies that included females only, and 12 studies that included males and females. Eight studies incorporated young adults (range of mean age: 30-44 years), whereas middle-aged adults were recruited in 9 studies (range of mean age: 45-56 years). In terms of occupational characteristics, 9 studies included blue collar workers and 8 studies examined white collar workers. Attendance rates ranged from 30 to 99% with only four studies reporting attendance rates ≥70% [14, 29].

Interventions (i.e., 25 PET groups in total) comprised resistance training (n = 10 intervention groups), endurance training (6), team sports activities (1), and multicomponent training (8). The PET interventions lasted between 8-52 weeks, at a frequency of 1-15 sessions per week, for duration of 7-60 min. Twenty PET intervention groups were classified as supervised and 4 were less supervised (in one intervention, the classification of training supervision was not applicable). Of note, some of the included articles referred to the same study but were different in terms of the fitness outcomes (i.e., [30] vs. [31], [15] vs. [32]).

A median PEDro score of 6 (range: 4-8) was detected for the included studies and 9 out of 17 studies reached the predetermined cut-off value ≥ 6 (Table 3).

3.2. Effects of physical exercise training conducted at the workplace on physical fitness

Figures 2 to 6 show the overall effects of PET compared with a passive control on measures of physical fitness. There were significant and small-sized effects of PET on measures of CRF (SMD_{wm} = 0.34, p = 0.002, I^2 = 69%, Chi^2 = 35.5, df = 11; Figure 2), muscular endurance (SMD_{wm} = 0.48, p < 0.001, I^2 = 10%, Chi^2 = 7.81, df = 7; Figure 4), and muscle power (SMD_{wm} = 0.29, p = 0.02, I^2 = 0%, Chi^2 = 2.54, df = 4; Figure 5). There were no significant effects of PET on muscle strength and balance ($-0.04 \leq SMD_{wm} \leq 0.35$, p > .05; Figures 3, 6).

3.3. Effects of sex, age, and occupation on fitness gains following physical exercise training conducted at the workplace

Table 4 shows the subgroup analyses according to sex, age, and occupation. Significant main effects of age were found on PET-induced CRF-responses (p = 0.02) with medium-sized effects in the subgroup young workers (SMD_{wm} = 0.71, p = 0.006). Further, significant main effects of occupation were observed on PET-induced responses in muscular endurance (p = 0.04) with medium-sized effects in the subgroup white-collar workers (SMD_{wm} = 0.60, p < 0.001).

3.4. Dose-response relationships of physical exercise training conducted at the workplace

Table 5 shows the results of a multivariate random effects meta-regression for program modalities of different categories including training period, frequency, session duration, and intensity. Due to the limited number of studies with sufficient information on these PET program modalities, meta-regression was calculated for CRF only. None of the training modalities (i.e., training period, frequency, session duration, and intensity) significantly predicted PET-induced CRF gains (p > 0.05). Explained between-study variance (R^2) was 0.00.

Table 6 shows subgroup analyses for different program modalities. Significant main effects of training period (p < 0.001) were shown on PET-induced changes in CRF. More precisely, the subgroup PET period of 9-12 weeks induced significant and small-sized effects (SMD_{wm} = 0.31, p = 0.009) and PET period of 17-20 weeks induced significant and medium-sized effects (SMD_{wm} = 0.74, p = 0.02).

4. DISCUSSION

This systematic review with meta-analysis examined the general effects as well as the age-, sex-, and occupation-specific impact of PET on physical fitness in the workforce. In addition, dose-response relationships of PET variables were computed. The main findings were that (a) PET has significant and small-sized effects on CRF, muscular endurance, and muscle power; (b) PET-induced gains in CRF and muscular endurance were particularly observed in young workers and white-collar workers, respectively; (c) Frequency, session duration, and intensity predict PET-induced CRF-enhancements.

4.1. Effects of physical exercise training conducted at the workplace on physical fitness

When PET is integrated in the workplace setting and performed at or nearby the workplace, PET can improve workers' physical fitness. More specifically, PET increases workers' CRF, muscular endurance, and muscle power. These results support the conclusions of previous narrative review articles that demonstrated fitness gains following PET [1, 10]. More precisely, improvements were reported in measures of CRF (5-14%) following PET in different workgroups (e.g., office workers, health care workers, cleaners) [1, 10]. Our aggregated results add fresh evidence that expands previous knowledge [13]. The corresponding changes in relative VO2max ranged from 1.8-3.9 ml/(min*kg) [33, 34]. Considering that every 1-ml/(min*kg) increase in VO2max is associated with a 45-day increase of longevity [35], this may result in a 81-176-day increase of longevity. Our study included only RCT's from the last two decades, all of which have been performed with less risk of bias and thorough methodologies. By doing so, we were able to appraise and synthesize current high-level evidence on the effects of PET on components of physical fitness in the workforce [16, 17].

Of note, higher levels of physical fitness can contribute to daily activities, mobility, occupational performance, and health in adults [5, 10, 13, 36, 37]. For instance, studies indicate that gains in CRF, muscle strength, and balance performance following PET programs can translate to reduced prevalence of neck, shoulder and back pain, higher workability and lower sickness absence [10]. Future studies need to systematically analyze the literature and aggregate the effects of PET programs on health-related outcomes as well as occupational performance in the workforce to confirm these findings.

4.2. Effects of sex, age, and type of occupation on fitness gains following physical exercise training conducted at the workplace

Sex and age influence physical performance across the lifespan. For instance, absolute muscle strength [38, 39], muscle power [38], and aerobic capacity [40] are lower whereas flexibility is greater [41] in females compared with males. Additionally, levels of these fitness components are in general lower in older compared with younger individuals [38–41] indicating that performance declines with aging. Several morphological and physiological factors contribute to the differences between sexes (e.g., muscle mass [42], airways [43], substrate utilization [44], fatigue resistance [45]) and ages (e.g., sarcopenia [46], loss of motor units [46]) affecting trainability. Moreover, in the working population, the type of occupation was introduced as an important individual fitness moderator [10] as strenuous and monotonous occupational physical activities may induce pain and discomfort, thereby impairing fitness measures [10].

We found that PET effects were age-dependent favoring workers aged <45 years. The interventions focused on endurance training at moderate-to-high intensities (60-95% maximum heart rate) in the intervention groups [15, 29, 34, 47]. A recent meta-analysis reported that continuous endurance training at moderate intensities (60-80% maximum heart rate) is effective to improve CRF indexed by VO_{2max} in young and middle-aged adults [48]. There seems to be an interaction between age and PET intensity because high-intensity interval training (90-95% maximum heart rate) preferentially improved CRF in older and less fit individuals compared with continuous endurance training [48]. The emerging recommendation is that young workers should perform PET (i.e., endurance training) at moderate-to-high intensities to improve their CRF. However, future studies need to examine whether high-intensity interval training in the workplace setting can further enhance CRF. This would be beneficial in relation to time savings as well as it may motivate more people to engage in PET, as time often has been proposed as a barrier [49].

Occupation can modify the effects of PET on muscular endurance with a significant and medium effect for the white-collar workers only. Traditionally, white-collar workers experience low physical work demands whereas blue-collar workers are exposed to high physical work demands [50]. Cross-sectional studies showed that high physical work demand is associated with low physical fitness [51, 52]. For instance, higher levels of physical demands as indicated by ratings of perceived exertion (scale 6-20) during a working day was associated with lower muscle strength values (e.g., maximum trunk extensor and handgrip strength) in middle-aged Finish municipal workers [51]. Additionally, workers with predominantly physical work demands showed impaired physical fitness (i.e., balance, trunk extensor muscular endurance) and cognitive performance and higher levels of perceived stress compared with workers who experience primarily mental work demands [53]. Further, in a recent RCT, a 12-month endurance training program at ≥60% VO2max improved CRF (i.e., VO2max) and other risk factors for cardiovascular diseases (e.g., waist circumference, resting heart rate) relative to a control group in middle-aged cleaners [47]. However, stratified analyses on the relative aerobic workload at baseline revealed that most of the beneficial training effects on risk factors remained only in workers with lower aerobic workloads of <30% heart rate reserve [47]. These results together with the findings from the present study support the model that high physical work demands (e.g., lifting heavy loads, repetitive and fatiguing movements, constrained postures) may induce pain and discomfort thereby mitigating specific PET effects in the development of fitness and/or health outcomes in the workforce [10]. Indeed, it was suggested to regularly include physical exercise into the weekly routines at the workplace in particular to counteract the negative effects of occupational tasks on physical fitness and health [1, 10]. Nevertheless, future studies need to identify appropriate PET programs conformed to the physical activities of the respective workplace. For instance, 12 months of endurance-type PET were conducted in a sample of cleaners in order to reduce the rating of perceived exertion and the need for recovery after the physically demanding workdays [54]. The study indicated that in the intervention compared with the control group, the need for recovery significantly decreased (-12%) after the intervention period with concomitant improvements in work ability (4%) [54]. Moreover, it was suggested to develop intelligent PET programs which take workers' individual physiological capacities relative to their occupational demands and disorders into account [15, 32, 55]. In this regard, a 1-year multicomponent intelligent PET revealed a significant increase in work ability (4%) and self-rated health status (9%) compared with a control group in office workers [56]. Additionally, productivity increased by 6% and absenteeism was reduced by 29% if adherence rate was ≥70%. Future studies in the form of randomized controlled trials are needed that specifically examine the role of work demands (e.g., comparing high vs. low physical work demand jobs) on the effectiveness of single PET programs to enhance physical fitness as well as health-related parameters (e.g., pain prevalence, perceived stress).

Interestingly, we did not observe any sex-specific effects on PET-related changes in physical fitness. However, in agreement with our findings, individual research studies comparing relative changes in muscle strength following resistance training [57, 58] and in CRF following endurance training [40] also indicated similar training-induced gains in males and females. It has to be noted though that we included data from female or male participants only or data pooled across sex. There is a gap in the literature directly analyzing the effects of PET in males versus females within one study design.

4.3. Dose-response relationships of physical exercise training conducted at the workplace

The current recommendations for adults consistently postulated a minimal dosage of 150 min a week of moderate-intensity aerobic activity (i.e., endurance training) and muscle strengthening exercises 2 days a week

[7–9]. To identify key training modalities that are responsible for the observed fitness gains following PET, we performed a multivariate random effects meta-regression analysis. The results indicated that none of the examined training modalities (i.e., training period, frequency, session duration, and intensity) significantly predicted improvements in CRF following PET. The applied statistical model explained 0% of the between-study variance. These findings imply that additional training modalities not included in the regression model (e.g., adherence rate) may have a major effect on PET to improve CRF.

In addition to meta-regression, independent subgroup analyses were conducted within each single training modality. In this regard, the current analyses revealed that the training period significantly modified the CRF responses to PET in workers. Training periods of 9-12 weeks and 17-20 weeks induced significantly small and medium effect, respectively, indicating that PET interventions should be performed for 4 to 5 months to improve workers' CRF. Milanovic et al. [48] previously showed in a systematic review and meta-analysis that endurance interventions of longer duration are more effective to improving VO_{2max} as a measure of CRF in young and middle-aged adults. This finding was recently reconfirmed in meta-analysis on the effects of PET on VO2peak in the workforce [59]. It seems reasonable to assume that intervention periods of >24 weeks may be even more effective to enhance CRF in workers. However, the included studies of long intervention periods (>24 weeks) specifically used an intention-to-treat analysis [15, 47]. Despite lower statistical power to find significant effects compared with per-protocol analyses, intention-to-treat analyses are used to reduce possible bias from differences in adherence rates [60]. Adherence rates in the long-term studies (>24 weeks intervention period) ranged from 51-56% [15, 47]. Adherence rates in most of the included short-to-medium-term studies (≤24 weeks) were higher (50-81%) [29, 34, 61, 62] which may in part explain the larger effectiveness to improve CRF. From a practitioner's point of view, special attention should be paid to the recruitment procedures for workplace health promotion programs. Further, appropriate strategies are required in public health promotion to make sustainable programs and participation [63].

An unexpected finding was a lack of effect by PET in general and resistance training in particular on muscle strength. The large heterogeneity of the studies could cause this negative finding, as this analysis included studies using resistance training only [22, 29, 33, 64, 65], soccer training [31], and multicomponent training comprising concurrent PET [32–34, 66] or combined resistance and balance training [14]. However, according to the concept of training specificity [67], intervention studies should consistently include strengthening exercises in their PET programs on a regular basis if the goal is to enhance muscle strength. In terms of multicomponent training, strength gains following concurrent training can be compromised when compared with single-mode resistance training (i.e., interference effect) particularly with increasing training experience [68]. Furthermore, intensities used in some resistance training groups ranged from 8- to 20-repetition maximum [22, 33, 64] or were not sufficiently reported [14, 29, 66]. Strengthening exercises with repetition maxima of ≤12 corresponding to 1-repetition maximum loads of ≥60% are required to develop muscle strength in adults [69]. Thus, less specific training stimuli, interference effects, and/or insufficient intensities during PET could partly explain that overall muscle strength was not enhanced following training.

Lastly, we found no effect of supervision on PET-induced fitness gains. In a recent randomized controlled trial, effects of supervised versus less supervised resistance training on muscle strength and muscular endurance were examined in healthy office workers [22]. In line with our systematic review and meta-analysis, similar fitness gains were observed in supervised (100% supervision) and less supervised (50% supervision) training groups when compared with a passive control group within the same study. Nevertheless, it was highlighted that supervision may be an important factor for PET adherence rate [22]. Additionally, supervision was suggested as a strategy to support sustained changes in physical activity behavior [70]. Furthermore, a systematic review with meta-analysis indicated that supervised resistance and/or balance training programs are more effective to improve muscle strength, muscle power, and balance than less supervised training programs in old adults aged ≥65 years [71]. Thus, physical fitness gains can be induced with lower levels of supervision (<50% supervised sessions) in young workers as long as simple exercises are performed with appropriate initial exercise instructions. However, supervision may become more important with older workforce to promote exercise motivation and physical activity behavior.

4.4. Limitations

The considerable heterogeneity (i.e., I^2 = 0-93%) among all studies is the strongest limitation of this systematic review and meta-analysis. Subgroup analysis helped to identify potential reasons for the observed magnitudes in heterogeneity. Another limitation is that univariate subgroup analyses were computed independently without controlling for interdependencies in the PET protocol. Comparative studies are needed in addition to meta-analyses to examine the effects of one training modality while the other modalities are kept constant. Further limitations of this systematic review and meta-analysis are the high risk of bias of some of the included studies (9 out of 17 studies reached the predetermined cut-off value of ≥ 6) and the uneven distribution of SMDs calculated for the respective fitness measures.

5. CONCLUSIONS

PET at work can improve CRF, muscular endurance, and muscle power in the working population. Age and type of occupation appeared to moderate these effects (CRF, muscular endurance). However, 47% percent of the included studies were at high risk of bias, so the results should be interpreted with caution. Findings from the meta-regression showed that the examined key training modalities (e.g., training period, training frequency) did not predict the effects of PET on CRF. However, independently computed subgroup analyses indicated that training periods of 17-20 weeks showed the largest effects of PET on cardiorespiratory fitness. The physiological capacity of the employees relative to occupational demands should be taken into account and intelligent PET programs should be tailored individually.

Compliance with ethical standards

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Conflicts of interest

Olaf Prieske, Tina Dalager, Michael Herz, Tibor Hortobágyi, Gisela Sjøgaard, Karen Søgaard and Urs Granacher declare that they have no conflicts of interest relevant to the content of this review.

Data availability

The datasets used and/or analyzed during the current study are available from the corre-sponding author on reasonable request.

Authors' contributions

OP, TD, KS, and UG: Made substantial contributions to conception and design; OP, TD, and MH: Contributed to data collection; OP, TD, and MH: Carried out data analysis and interpretation together with TH, GS, KS, and UG; OP: Wrote the first draft of the manuscript and all authors were involved in revising it critically for important intellectual content; All authors gave final approval of the version to be published and agreed to be accountable for all aspects of the work.

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TABLES

Table 1: Study coding.

Table 2: Studies examining the effects of physical exercise training at the workplace on measures of physical fitness in the workforce.

Table 3: Physiotherapy Evidence Database (PEDro) score of the included randomized controlled trials.

Table 4: Overall effects of physical exercise training on measures of physical fitness as well as subgroup-specific effects for moderator variables.

Table 5: Results of the multivariate random effects meta-regression analyses for program modalities of different categories to predict effects of physical exercise training conducted at the workplace on cardiorespiratory fitness.

Table 6: Overall effects of physical exercise training on measures of physical fitness as well as subgroup-specific effects for program modalities.

FIGURES

Figure 1: Flowchart illustrating each phase of the search and selecting process.

Figure 2: Effects of physical exercise training (PET) versus control condition on measures of cardiorespiratory fitness in workers. *CI* confidence interval, *df* degrees of freedom, *IV* inverse, *SMD* standardized mean difference

Figure 3: Effects of physical exercise training (PET) versus control condition on measures of muscle strength in workers. *CI* confidence interval, *df* degrees of freedom, *IV* inverse, *SMD* standardized mean difference

Figure 4: Effects of physical exercise training (PET) versus control condition on measures of muscular endurance in workers. *CI* confidence interval, *df* degrees of freedom, *IV* inverse, *SMD* standardized mean difference

Figure 5: Effects of physical exercise training (PET) versus control condition on measures of muscle power in workers. *CI* confidence interval, *df* degrees of freedom, *IV* inverse, *SMD* standardized mean difference

Figure 6: Effects of physical exercise training (PET) versus control condition on measures of balance in workers. *CI* confidence interval, *df* degrees of freedom, *IV* inverse, *SMD* standardized mean difference

Effects of physical exercise training in the workplace on physical fitness: a systematic review and meta-analysis

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ABSTRACT

Background

There is evidence that physical exercise training (PET) conducted at the workplace is effective in improving physical fitness and thus health. However, there is no current systematic review available that provides high-level evidence regarding the effects of PET on physical fitness in the workforce.

Objectives

To quantify sex-, age-, and occupation type-specific effects of PET on physical fitness and to characterize dose-response relationships of PET modalities that could maximize gains in physical fitness in the working population.

Data sources

A computerized systematic literature search was conducted in the databases PubMed and Cochrane Library (2000-2019) to identify articles related to PET in workers.

Study eligibility criteria

Only randomized controlled trials with a passive control group were included if they investigated the effects of PET programs in workers and tested at least one fitness measure.

Study appraisal and synthesis methods

Weighted mean standardised mean differences (SMD_{wm}) were calculated using random effects models. A multivariate random effects meta-regression was computed to explain the influence of key training modalities (e.g., training frequency, session duration, intensity) on the effectiveness of PET on measures of physical fitness. Further, subgroup univariate analyses were computed for each training modality. Additionally, methodological quality of the included studies was rated with the help of the Physiotherapy Evidence Database (PEDro)Scale.

Results

Overall, 3,423 workers aged 30-56 years participated in 17 studies (19 articles) that were eligible for inclusion. Methodological quality of the included studies was moderate with a median PEDro score of 6. Our analyses revealed significant, small-sized effects of PET on cardiorespiratory fitness (CRF), muscular endurance, and muscle power ($0.29 \leq SMD_{wm} \leq 0.48$). Medium effects were found for CRF and muscular endurance in younger workers (≤45 years) ($SMD_{wm}=0.71$) and white-collar workers ($SMD_{wm}=0.60$), respectively. Multivariate random effects meta-regression for CRF revealed that none of the examined training modalities predicted the effects of PET on CRF ($R^2=0$). Independently computed subgroup analyses showed significant PET effects on CRF when conducted for 9-12 weeks ($SMD_{wm}=0.31$) and for 17-20 weeks ($SMD_{wm}=0.74$).

Conclusions

PET effects on physical fitness in healthy workers are moderated by age (CRF) and occupation type (muscular endurance). Further, independently computed subgroup analyses indicated that the training period of the PET programs may play an important role in improving CRF in workers.

KEY POINTS

- Physical exercise training conducted at the workplace significantly improved cardiorespiratory fitness, muscular endurance, and muscle power in the working population.
- The effects of physical exercise training at the workplace were moderated by age and occupation type. Only young workers showed training-induced gains in cardiorespiratory fitness. Increments in muscular endurance were found in white-collar workers only.
- Our dose-response relationships revealed that the examined key training modalities (e.g., training period, training frequency) did not predict the effects of physical exercise training on cardiorespiratory fitness. However, independently computed subgroup analyses indicated that training periods of 17-20 weeks showed the largest effects of physical exercise training on cardiorespiratory fitness.

1. INTRODUCTION

Previous studies have reported a significant relationship between physical fitness and work performance, health, daily life activities, and mobility [1–3]. In general, physical fitness is defined as a set of health- or skill-related attributes (e.g., cardiorespiratory fitness [CRF], muscle strength, balance) that people have or achieve to carry out daily tasks [4]. Higher levels of physical fitness as indicated by upper- and lower-body strength are associated with a lower risk of all-cause mortality in adults across the lifespan [5]. Further, Christensen et al. [6] examined associations between changes in physical fitness and on-the-job performance following three months of a multifactorial intervention program in healthcare workers. The authors reported significant and medium-sized correlations between increments in trunk flexor/extensor strength and gains in on-the-job performance ($.411 \leq$ Pearson's $r \leq .456$), indicating the importance of physical fitness for the working population (i.e., workforce).

In order to improve or maintain physical fitness in adults and seniors, current international physical activity recommendations suggest a minimum dosage of at least 150 min/week of moderate-to-vigorous intensity [7–9]. Physical activity comprises any physical movements produced by skeletal muscles that results in energy expenditure [4]. Interestingly, it was recently highlighted that not all physical activities contribute to fitness and health [10–12]. Occupational physical activities such as lifting heavy loads, repetitive and fatiguing movements, or constrained postures may induce pain and discomfort, thereby decreasing physical fitness [10]. Further, physically demanding work tends to increase the risk for long-term sickness absence and early mortality especially in males, even after adjustment for relevant confounders such as leisure time physical activity, alcohol intake and/or smoking [11, 12]. Thus, it was suggested to regularly include well-structured health-enhancing physical exercises into weekly routines at the workplace to counteract the negative side effects of monotonous physical tasks at work [1, 10]. Further, given that most adults spend half of their waking hours at the workplace, the worksite setting offers a unique opportunity to promote physical activity and fitness as well as engage individuals who might not otherwise participate in physical exercise training.

So far, the literature on the effects of physical exercise training (PET) conducted at the workplace on physical fitness is controversial [13]. According to Caspersen et al. [4] and Garber et al. [7], PET refers to any planned, structured, and repetitive physical activity with the goal to maintain or improve physical fitness and/or health. Methodological limitations (e.g., randomization, blinding, poor compliance) accounted for the many inconsistencies. Since 2003, high-quality randomized and controlled trials (RCTs) have demonstrated that workers' physical fitness can benefit from PET programs [14, 15], making a fresh review of the topic relevant. For example, an 8-week combined balance and strength training compared with a passive control group significantly improved muscle strength, power, and balance in middle-aged workers [14]. One year combined strength and endurance training compared with passive controls significantly enhanced CRF in office workers [15].

To the best of our knowledge, there is currently no systematic review and meta-analysis available that included RCTs only and thus provides the highest level on the evidence-based medicine pyramid regarding the effects of PET on physical fitness (e.g., CRF, muscle strength, balance) in the workforce [16, 17]. Additionally, there is scarce information on how to optimize training effects on physical fitness measures and to avoid over- or under-prescription of PET.

Thus, in an exploratory approach, the objectives of this systematic literature review and meta-analysis were to i) analyse the effects of PET on physical fitness measures in the workforce including potentially modify-ing variables such as age, sex, and type of occupation, and ii) characterize dose-response relationships of PET parameters (e.g., training period, session duration, frequency, intensity) by quantitative analyses of PET studies in workers. We hypothesized that i) PET has a beneficial effect on physical fitness in the workforce, and ii) the effects are moderated by age, sex, and type of occupation.

2. METHODS

Our systematic literature review was conducted in accordance with the recommendations of the ''Preferred Reporting Items for Systematic Reviews and Meta-Analyses'' (PRISMA) [18].

2.1. Literature search

We performed a computerized systematic literature review in the electronic databases PubMed and Cochrane Library from 01/01/2000 to 30/06/2019. A Boolean-search strategy was used with the operators "AND", "NOT" and "OR" as well as study keywords related to physical fitness, PET, and workers (Table S1). The search was limited to ages (18-65 years) and languages (English, German). Further, the reference lists of the included studies and relevant review articles [1, 10, 13, 19] were screened for titles to identify additional adequate references for inclusion in our meta-analysis.

2.2. Eligibility criteria for selecting studies

Studies were included in this systematic review and meta-analysis if they provided relevant information with regards to the PICOS approach (i.e., participants, interventions, comparators, outcomes, and study design) [18]. The following criteria were predefined for inclusion: (a) full-text availability; (b) population: workers with mean ages ranging from 18 to 65 years; (c) intervention: PET programs for the promotion of physical activity/fitness (e.g., cardiovascular training, strength training, team sport activities) performed at or nearby the workplace; (d) comparator: passive control group (i.e., no alternative training) maintaining its regular activity behaviour; (e) outcome: at least one measure of CRF, muscle strength, muscular endurance, muscle power, and/or balance; (f) study design: RCT.

Studies were excluded if they: (a) specifically included patient populations only (e.g., hypertension, type 2 diabetes); (b) had no control group or alternative intervention groups (e.g., behavioural training) only; (c) did not meet the minimum requirements regarding the description of at least one training modality (e.g., training duration, frequency, or intensity); (d) did not report results adequately (i.e., means and standard deviations/errors) or if respective authors did not reply to our inquiries sent by email. Based on the a priori defined inclusion and exclusion criteria, two independent reviewers (OP, MH) screened potentially relevant articles by analysing titles, abstracts, and full texts of the respective articles to elucidate their eligibility. In case MH and OP did not reach an agreement concerning the inclusion of an article, a third author (UG or TD) was contacted.

2.3. Coding of studies

All included studies were coded for the variables listed in Table 1. A template from previous systematic reviews and meta analyses of our research group was used to extract data [20, 21]. One author (MH) extracted the data from the included studies and a second author (OP) double-checked the extracted data. Disagreements were resolved through personal communication between the two authors (MH, OP). If no agreement was achieved, a third author was contacted (TD) to solve previous disagreement. Our analyses focused on different measures of physical fitness. If studies reported multiple variables within one of these fitness components, only one representative outcome variable was included in the analyses. The variable with the highest priority for each outcome was illustrated in Table 1. If studies reported outcome variables other than the preferred variables, we included test variables that were most similar to the ones described above in terms of their temporal/ spatial structure.

Further, we coded PET according to the following training parameters: training type (e.g., resistance training, endurance training), training period, frequency (i.e., sessions/week), session duration, intensity, and supervision (i.e., supervised, less supervised). If a study reported exercise progression over the training period, the mean number of frequency and session duration were computed. PET was defined as supervised if at least 50% of the sessions were attended by an instructor supervising the execution of exercises [22]. Accordingly, a training group was rated as less supervised, if less than 50% of the sessions were attended by an instructor. To obtain sufficient statistical power to calculate dose-response relationships, we computed our analyses irrespective of age, sex, and type of occupation.

2.4. Assessment of risk of bias

The Physiotherapy Evidence Database (PEDro) scale was used to quantify the risk of bias in eligible studies and to provide information on the general methodological quality of studies. The PEDro scale rates internal study validity and the presence of statistical replicable information on a scale from zero (high risk of bias) to ten (low risk of bias) with ≥6 representing a cut-off score for studies with low risk of bias [23]. In this regard, it has to be taken into account that it is impossible to blind participants and instructors in PET studies as rated by the PEDro scale. If available, one author of our research group (MH) obtained information on the PEDro scores of the respective studies from the PEDro database (www.pedro.org.au). If studies were not listed in the database, one author (MH) evaluated the respective studies according to the eleven items of the PEDro scale and a second author (OP) double-checked the scores.

2.5. Statistical analysis

To determine the effects of PET on physical fitness measures in the workforce, the between-subject standardized mean differences (SMD) were calculated according to the following equation: $SMD = \frac{m_1 - m_2}{s_{pooled}}$ where m_1 stands for the mean post-value of the PET group, m_2 for the mean post-value of the control group, and s_{pooled} for the pooled standard deviation. Whenever possible, data from intention-to-treat analyses were used. In accordance with Hedges and Olkin [24], the SMD was adjusted for the respective sample size by using the factor $\left(1 - \frac{3}{4N-9}\right)$ with N representing the total sample size. A random effects model was applied to weight each included articles according to the magnitude of the respective standard error and to finally calculate the weighted mean SMD (SMD_{wm}). SMD_{wm} were aggregated for the respective outcomes if the training type was specific for the outcome (e.g., endurance training, team sports, and multicomponent training for CRF). Subgroup univariate analyses for moderator variables (i.e., sex, age, type of occupation) were computed by aggregating SMD_{wm} values for specific subgroups by comparing subgroup effect sizes for statistically significant differences using a Chi² trend test. To specify dose–response relationships, additional subgroup univariate analyses were calculated for program modalities (i.e., training type, training period, frequency, session duration, intensity, supervision). Additionally, multivariate random effects meta-regressions were computed with Comprehensive Meta-analysis version 3.3.07 (Biostat Inc., Englewood, NJ, USA) to verify if any of the examined program modalities predict the effectiveness of PET in the workforce. At least two PET intervention groups had to be included to calculate SMDs, for each proxy of physical fitness [25]. This meta-analysis was conducted using Review Manager 5.3 (Nordic Cochrane Centre, Copenhagen, Denmark). Positive SMD values were consistently reported if the effects were in favour of PET compared with a control. For data interpretation, effect size values of $SMD < 0.50$ indicate small, of $0.50 \leq SMD < 0.80$ indicate medium, and of $SMD \geq 0.80$ indicate large effects [26]. Further, between-study heterogeneity was assessed using I^2 and Chi² statistics. Heterogeneity was interpreted as low ($I^2 \leq 25\%$), moderate ($25\% < I^2 \leq 50\%$), high ($50\% < I^2 \leq 75\%$), or considerable ($I^2 > 75\%$) [27, 28]. The level of significance was set at $p < .05$.

3. RESULTS

3.1. Study characteristics

A total of 515 potentially relevant articles were identified by the searches (Figure 1). Finally, 17 studies (19 articles; n = 3,423 workers at baseline; 1,065 men, 2,358 women) remained for the quantitative analysis. The sample size in the individual studies ranged from 19-730 participants (Table 2). There were 2 studies that included males only, 3 studies that included females only, and 12 studies that included males and females. Eight studies incorporated young adults (range of mean age: 30-44 years), whereas middle-aged adults were recruited in 9 studies (range of mean age: 45-56 years). In terms of occupational characteristics, 9 studies included blue collar workers and 8 studies examined white collar workers. Attendance rates ranged from 30 to 99% with only four studies reporting attendance rates ≥70% [14, 29].

Interventions (i.e., 25 PET groups in total) comprised resistance training (n = 10 intervention groups), endurance training (6), team sports activities (1), and multicomponent training (8). The PET interventions lasted between 8-52 weeks, at a frequency of 1-15 sessions per week, for duration of 7-60 min. Twenty PET intervention groups were classified as supervised and 4 were less supervised (in one intervention, the classification of training supervision was not applicable). Of note, some of the included articles referred to the same study but were different in terms of the fitness outcomes (i.e., [30] vs. [31], [15] vs. [32]).

A median PEDro score of 6 (range: 4-8) was detected for the included studies and 9 out of 17 studies reached the predetermined cut-off value ≥ 6 (Table 3).

3.2. Effects of physical exercise training conducted at the workplace on physical fitness

Figures 2 to 6 show the overall effects of PET compared with a passive control on measures of physical fitness. There were significant and small-sized effects of PET on measures of CRF (SMD_{wm} = 0.34, p = 0.002, I^2 = 69%, Chi^2 = 35.5, df = 11; Figure 2), muscular endurance (SMD_{wm} = 0.48, p < 0.001, I^2 = 10%, Chi^2 = 7.81, df = 7; Figure 4), and muscle power (SMD_{wm} = 0.29, p = 0.02, I^2 = 0%, Chi^2 = 2.54, df = 4; Figure 5). There were no significant effects of PET on muscle strength and balance (-0.04 ≤ SMD_{wm} ≤ 0.35, p > .05; Figures 3, 6).

3.3. Effects of sex, age, and occupation on fitness gains following physical exercise training conducted at the workplace

Table 4 shows the subgroup analyses according to sex, age, and occupation. Significant main effects of age were found on PET-induced CRF-responses (p = 0.02) with medium-sized effects in the subgroup young workers (SMD_{wm} = 0.71, p = 0.006). Further, significant main effects of occupation were observed on PET-induced responses in muscular endurance (p = 0.04) with medium-sized effects in the subgroup white-collar workers (SMD_{wm} = 0.60, p < 0.001).

3.4. Dose-response relationships of physical exercise training conducted at the workplace

Table 5 shows the results of a multivariate random effects meta-regression for program modalities of different categories including training period, frequency, session duration, and intensity. Due to the limited number of studies with sufficient information on these PET program modalities, meta-regression was calculated for CRF only. None of the training modalities (i.e., training period, frequency, session duration, and intensity) significantly predicted PET-induced CRF gains (p > 0.05). Explained between-study variance (R^2) was 0.00.

Table 6 shows subgroup analyses for different program modalities. Significant main effects of training period (p < 0.001) were shown on PET-induced changes in CRF. More precisely, the subgroup PET period of 9-12 weeks induced significant and small-sized effects (SMD_{wm} = 0.31, p = 0.009) and PET period of 17-20 weeks induced significant and medium-sized effects (SMD_{wm} = 0.74, p = 0.02).

4. DISCUSSION

This systematic review with meta-analysis examined the general effects as well as the age-, sex-, and occupation-specific impact of PET on physical fitness in the workforce. In addition, dose-response relationships of PET variables were computed. The main findings were that (a) PET has significant and small-sized effects on CRF, muscular endurance, and muscle power; (b) PET-induced gains in CRF and muscular endurance were particularly observed in young workers and white-collar workers, respectively; (c) Frequency, session duration, and intensity predict PET-induced CRF-enhancements.

4.1. Effects of physical exercise training conducted at the workplace on physical fitness

When PET is integrated in the workplace setting and performed at or nearby the workplace, PET can improve workers' physical fitness. More specifically, PET increases workers' CRF, muscular endurance, and muscle power. These results support the conclusions of previous narrative review articles that demonstrated fitness gains following PET [1, 10]. More precisely, improvements were reported in measures of CRF (5-14%) following PET in different workgroups (e.g., office workers, health care workers, cleaners) [1, 10]. Our aggregated results add fresh evidence that expands previous knowledge [13]. The corresponding changes in relative VO2max ranged from 1.8-3.9 ml/(min*kg) [33, 34]. Considering that every 1-ml/(min*kg) increase in VO2max is associated with a 45-day increase of longevity [35], this may result in a 81-176-day increase of longevity. Our study included only RCT's from the last two decades, all of which have been performed with less risk of bias and thorough methodologies. By doing so, we were able to appraise and synthesize current high-level evidence on the effects of PET on components of physical fitness in the workforce [16, 17].

Of note, higher levels of physical fitness can contribute to daily activities, mobility, occupational performance, and health in adults [5, 10, 13, 36, 37]. For instance, studies indicate that gains in CRF, muscle strength, and balance performance following PET programs can translate to reduced prevalence of neck, shoulder and back pain, higher workability and lower sickness absence [10]. Future studies need to systematically analyze the literature and aggregate the effects of PET programs on health-related outcomes as well as occupational performance in the workforce to confirm these findings.

4.2. Effects of sex, age, and type of occupation on fitness gains following physical exercise training conducted at the workplace

Sex and age influence physical performance across the lifespan. For instance, absolute muscle strength [38, 39], muscle power [38], and aerobic capacity [40] are lower whereas flexibility is greater [41] in females compared with males. Additionally, levels of these fitness components are in general lower in older compared with younger individuals [38–41] indicating that performance declines with aging. Several morphological and physiological factors contribute to the differences between sexes (e.g., muscle mass [42], airways [43], substrate utilization [44], fatigue resistance [45]) and ages (e.g., sarcopenia [46], loss of motor units [46]) affecting trainability. Moreover, in the working population, the type of occupation was introduced as an important individual fitness moderator [10] as strenuous and monotonous occupational physical activities may induce pain and discomfort, thereby impairing fitness measures [10].

We found that PET effects were age-dependent favoring workers aged <45 years. The interventions focused on endurance training at moderate-to-high intensities (60-95% maximum heart rate) in the intervention groups [15, 29, 34, 47]. A recent meta-analysis reported that continuous endurance training at moderate intensities (60-80% maximum heart rate) is effective to improve CRF indexed by VO_{2max} in young and middle-aged adults [48]. There seems to be an interaction between age and PET intensity because high-intensity interval training (90-95% maximum heart rate) preferentially improved CRF in older and less fit individuals compared with continuous endurance training [48]. The emerging recommendation is that young workers should perform PET (i.e., endurance training) at moderate-to-high intensities to improve their CRF. However, future studies need to examine whether high-intensity interval training in the workplace setting can further enhance CRF. This would be beneficial in relation to time savings as well as it may motivate more people to engage in PET, as time often has been proposed as a barrier [49].

Occupation can modify the effects of PET on muscular endurance with a significant and medium effect for the white-collar workers only. Traditionally, white-collar workers experience low physical work demands whereas blue-collar workers are exposed to high physical work demands [50]. Cross-sectional studies showed that high physical work demand is associated with low physical fitness [51, 52]. For instance, higher levels of physical demands as indicated by ratings of perceived exertion (scale 6-20) during a working day was associated with lower muscle strength values (e.g., maximum trunk extensor and handgrip strength) in middle-aged Finish municipal workers [51]. Additionally, workers with predominantly physical work demands showed impaired physical fitness (i.e., balance, trunk extensor muscular endurance) and cognitive performance and higher levels of perceived stress compared with workers who experience primarily mental work demands [53]. Further, in a recent RCT, a 12-month endurance training program at ≥60% VO2max improved CRF (i.e., VO2max) and other risk factors for cardiovascular diseases (e.g., waist circumference, resting heart rate) relative to a control group in middle-aged cleaners [47]. However, stratified analyses on the relative aerobic workload at baseline revealed that most of the beneficial training effects on risk factors remained only in workers with lower aerobic workloads of <30% heart rate reserve [47]. These results together with the findings from the present study support the model that high physical work demands (e.g., lifting heavy loads, repetitive and fatiguing movements, constrained postures) may induce pain and discomfort thereby mitigating specific PET effects in the development of fitness and/or health outcomes in the workforce [10]. Indeed, it was suggested to regularly include physical exercise into the weekly routines at the workplace in particular to counteract the negative effects of occupational tasks on physical fitness and health [1, 10]. Nevertheless, future studies need to identify appropriate PET programs conformed to the physical activities of the respective workplace. For instance, 12 months of endurance-type PET were conducted in a sample of cleaners in order to reduce the rating of perceived exertion and the need for recovery after the physically demanding workdays [54]. The study indicated that in the intervention compared with the control group, the need for recovery significantly decreased (-12%) after the intervention period with concomitant improvements in work ability (4%) [54]. Moreover, it was suggested to develop intelligent PET programs which take workers' individual physiological capacities relative to their occupational demands and disorders into account [15, 32, 55]. In this regard, a 1-year multicomponent intelligent PET revealed a significant increase in work ability (4%) and self-rated health status (9%) compared with a control group in office workers [56]. Additionally, productivity increased by 6% and absenteeism was reduced by 29% if adherence rate was ≥70%. Future studies in the form of randomized controlled trials are needed that specifically examine the role of work demands (e.g., comparing high vs. low physical work demand jobs) on the effectiveness of single PET programs to enhance physical fitness as well as health-related parameters (e.g., pain prevalence, perceived stress).

Interestingly, we did not observe any sex-specific effects on PET-related changes in physical fitness. However, in agreement with our findings, individual research studies comparing relative changes in muscle strength following resistance training [57, 58] and in CRF following endurance training [40] also indicated similar training-induced gains in males and females. It has to be noted though that we included data from female or male participants only or data pooled across sex. There is a gap in the literature directly analyzing the effects of PET in males versus females within one study design.

4.3. Dose-response relationships of physical exercise training conducted at the workplace

The current recommendations for adults consistently postulated a minimal dosage of 150 min a week of moderate-intensity aerobic activity (i.e., endurance training) and muscle strengthening exercises 2 days a week

[7–9]. To identify key training modalities that are responsible for the observed fitness gains following PET, we performed a multivariate random effects meta-regression analysis. The results indicated that none of the examined training modalities (i.e., training period, frequency, session duration, and intensity) significantly predicted improvements in CRF following PET. The applied statistical model explained 0% of the between-study variance. These findings imply that additional training modalities not included in the regression model (e.g., adherence rate) may have a major effect on PET to improve CRF.

In addition to meta-regression, independent subgroup analyses were conducted within each single training modality. In this regard, the current analyses revealed that the training period significantly modified the CRF responses to PET in workers. Training periods of 9-12 weeks and 17-20 weeks induced significantly small and medium effect, respectively, indicating that PET interventions should be performed for 4 to 5 months to improve workers' CRF. Milanovic et al. [48] previously showed in a systematic review and meta-analysis that endurance interventions of longer duration are more effective to improving VO_{2max} as a measure of CRF in young and middle-aged adults. This finding was recently reconfirmed in meta-analysis on the effects of PET on VO2peak in the workforce [59]. It seems reasonable to assume that intervention periods of >24 weeks may be even more effective to enhance CRF in workers. However, the included studies of long intervention periods (>24 weeks) specifically used an intention-to-treat analysis [15, 47]. Despite lower statistical power to find significant effects compared with per-protocol analyses, intention-to-treat analyses are used to reduce possible bias from differences in adherence rates [60]. Adherence rates in the long-term studies (>24 weeks intervention period) ranged from 51-56% [15, 47]. Adherence rates in most of the included short-to-medium-term studies (≤24 weeks) were higher (50-81%) [29, 34, 61, 62] which may in part explain the larger effectiveness to improve CRF. From a practitioner's point of view, special attention should be paid to the recruitment procedures for workplace health promotion programs. Further, appropriate strategies are required in public health promotion to make sustainable programs and participation [63].

An unexpected finding was a lack of effect by PET in general and resistance training in particular on muscle strength. The large heterogeneity of the studies could cause this negative finding, as this analysis included studies using resistance training only [22, 29, 33, 64, 65], soccer training [31], and multicomponent training comprising concurrent PET [32–34, 66] or combined resistance and balance training [14]. However, according to the concept of training specificity [67], intervention studies should consistently include strengthening exercises in their PET programs on a regular basis if the goal is to enhance muscle strength. In terms of multicomponent training, strength gains following concurrent training can be compromised when compared with single-mode resistance training (i.e., interference effect) particularly with increasing training experience [68]. Furthermore, intensities used in some resistance training groups ranged from 8- to 20-repetition maximum [22, 33, 64] or were not sufficiently reported [14, 29, 66]. Strengthening exercises with repetition maxima of ≤12 corresponding to 1-repetition maximum loads of ≥60% are required to develop muscle strength in adults [69]. Thus, less specific training stimuli, interference effects, and/or insufficient intensities during PET could partly explain that overall muscle strength was not enhanced following training.

Lastly, we found no effect of supervision on PET-induced fitness gains. In a recent randomized controlled trial, effects of supervised versus less supervised resistance training on muscle strength and muscular endurance were examined in healthy office workers [22]. In line with our systematic review and meta-analysis, similar fitness gains were observed in supervised (100% supervision) and less supervised (50% supervision) training groups when compared with a passive control group within the same study. Nevertheless, it was highlighted that supervision may be an important factor for PET adherence rate [22]. Additionally, supervision was suggested as a strategy to support sustained changes in physical activity behavior [70]. Furthermore, a systematic review with meta-analysis indicated that supervised resistance and/or balance training programs are more effective to improve muscle strength, muscle power, and balance than less supervised training programs in old adults aged ≥65 years [71]. Thus, physical fitness gains can be induced with lower levels of supervision (<50% supervised sessions) in young workers as long as simple exercises are performed with appropriate initial exercise instructions. However, supervision may become more important with older workforce to promote exercise motivation and physical activity behavior.

4.4. Limitations

The considerable heterogeneity (i.e., I^2 = 0-93%) among all studies is the strongest limitation of this systematic review and meta-analysis. Subgroup analysis helped to identify potential reasons for the observed magnitudes in heterogeneity. Another limitation is that univariate subgroup analyses were computed independently without controlling for interdependencies in the PET protocol. Comparative studies are needed in addition to meta-analyses to examine the effects of one training modality while the other modalities are kept constant. Further limitations of this systematic review and meta-analysis are the high risk of bias of some of the included studies (9 out of 17 studies reached the predetermined cut-off value of ≥ 6) and the uneven distribution of SMDs calculated for the respective fitness measures.

5. CONCLUSIONS

PET at work can improve CRF, muscular endurance, and muscle power in the working population. Age and type of occupation appeared to moderate these effects (CRF, muscular endurance). However, 47% percent of the included studies were at high risk of bias, so the results should be interpreted with caution. Findings from the meta-regression showed that the examined key training modalities (e.g., training period, training frequency) did not predict the effects of PET on CRF. However, independently computed subgroup analyses indicated that training periods of 17-20 weeks showed the largest effects of PET on cardiorespiratory fitness. The physiological capacity of the employees relative to occupational demands should be taken into account and intelligent PET programs should be tailored individually.

Compliance with ethical standards

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Conflicts of interest

Olaf Prieske, Tina Dalager, Michael Herz, Tibor Hortobágyi, Gisela Sjøgaard, Karen Søgaard and Urs Granacher declare that they have no conflicts of interest relevant to the content of this review.

Data availability

The datasets used and/or analyzed during the current study are available from the corre-sponding author on reasonable request.

Authors' contributions

OP, TD, KS, and UG: Made substantial contributions to conception and design; OP, TD, and MH: Contributed to data collection; OP, TD, and MH: Carried out data analysis and interpretation together with TH, GS, KS, and UG; OP: Wrote the first draft of the manuscript and all authors were involved in revising it critically for important intellectual content; All authors gave final approval of the version to be published and agreed to be accountable for all aspects of the work.

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TABLES

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FIGURES

Figure 1: Flowchart illustrating each phase of the search and selecting process.

Figure 2: Effects of physical exercise training (PET) versus control condition on measures of cardiorespiratory fitness in workers. *CI* confidence interval, *df* degrees of freedom, *IV* inverse, *SMD* standardized mean difference

Figure 3: Effects of physical exercise training (PET) versus control condition on measures of muscle strength in workers. *CI* confidence interval, *df* degrees of freedom, *IV* inverse, *SMD* standardized mean difference

Figure 4: Effects of physical exercise training (PET) versus control condition on measures of muscular endurance in workers. *CI* confidence interval, *df* degrees of freedom, *IV* inverse, *SMD* standardized mean difference

Figure 5: Effects of physical exercise training (PET) versus control condition on measures of muscle power in workers. *CI* confidence interval, *df* degrees of freedom, *IV* inverse, *SMD* standardized mean difference

Figure 6: Effects of physical exercise training (PET) versus control condition on measures of balance in workers. *CI* confidence interval, *df* degrees of freedom, *IV* inverse, *SMD* standardized mean difference

Table 1: Study coding

Sex	• Male participants only • Female participants only • Combined male and female participants
Age [12]	• Young adults (18-44 years) • Middle-aged adults (45-65 years)
Type of occupation [44]	• Blue collar workers (e.g., labor, industry, farming, transportation) • White collar workers (e.g., office, civil service)
Outcome categories [2]	• Cardiorespiratory fitness (preferred relative VO_{2max}) • muscle strength (preferred maximal isometric trunk flexor force/torque) • muscular endurance (preferred static plank test time) • muscle power (preferred countermovement jump height) • balance (preferred center of pressure displacement during bipedal standing)

Table 2: Studies examining the effects of physical exercise training at the workplace on measures of physical fitness in the workforce.

Study	*Job*	*Sex*	*Age*	*Type of occupation*	*N*	*Adherence*	*Training intervention*							*Tests (Outcomes)*
							Training type	*Exercises*	*Training period (weeks)*	*Frequency (x/ week)*	*Duration (min)*	*Intensity*	*Supervision*	
Barene et al. [30, 31]	Hospital employees	F (107)	46±9	Blue	IG1: 37 IG2: 35 CG: 35	NA	IG1: team sports IG2: endurance	Soccer training Zumba	12, 36 12, 36	2,5 2,5	60 60	low to vigorous low to vigorous	S, L S	Maximal cycle ergometer (VO2peak) Isometric dynamometry (trunk extensor MIF) Single leg stance (COP displacement) Countermovement jump (jump height)
Brox and Frøystein [62]	Nursing home workers	M (4), F (115)	46±9	Blue		<50%	Endurance	Aerobic fitness	24	1	60	NA	S	UKK walking (CRF index)
Dalager et al. [22]	Office workers	M (222), F (351)	46±11	White	IG1: 116 IG2: 126 IG3: 106 IG4: 124 CG: 101	33-44%	IG1: Resistance IG2: Resistance IG3: Resistance IG4: Resistance	Free weights Free weights Free weights Free weights	20 20 20 20	1 3 9 3	60 20 7 20	8-20RM 8-20RM 8-20RM 8-20RM moderate to vigorous	S S S L	Maximal dynamic lateral rise (1-RM)
Dalager et al. [15,	Office workers	M (101),	44±10	White	IG: 193 CG: 194	56%	Multicomponent	Running/rowing/ball	52	1	60	Moderate to vigorous (60-	S	Submaximal cycle ergome-

32]		F (286)						games; neck/trunk/chest strengthening				80% 1 RM, 77-95% HR)		ter (VO2max*) Isometric dynamometry (trunk extensor MIF)
Genin et al. [66]	Office workers	M (62), F (33)	44±10	White	IG1: 36 IG2: 37 CG: 22	NA	IG1: multicomponent (trained) IG2: multicomponent (untrained)	Dance/step/bike; Machine-based strengthening	20 20	2 2	45 45	NA NA	S S	6 min walk (max. distance) Isometric dynamometry (hand grip MIF) Biering-Sørensen (trunk muscle endurance time) Countermovement jump (jump height) Flamingo test (stance time)
Gram et al. [34]	Construction workers	M (67)	44±11	Blue	IG: 35 CG: 32	68%	Multicomponent	Running/rowing/; neck/trunk/chest strengthening	12	3	20	Moderate to vigorous (60% 1 RM, 70% VO_{2max})	S	Submaximal cycle ergometer (VO2max*) Isometric dynamometry (trunk extensor MIF)
Granacher et al. [14]	Office workers	M (23), F (9)	56±4	White	IG: 17 CG: 15	99%	Multicomponent	Lower limb strengthening; balance	8	15	8	Moderate (15 reps)	L	Isometric dynamometry (leg extensor MIF/RFD) Single leg stance (COP displacement)
Hamberg-	Office	M (6),	37±9	White	IG: 9	64%	Resistance	Shoulder/core	8	2	60	Moderate to	NA	Isometric dy-

van Reenen et al. [64]	workers	F (13)			CG: 10			strengthening				vigorous (10-15RM)		namometry (trunk extensor MIF)
Jørgensen et al. [65]	Cleaners	F (294)	45±9	Blue	IG1: 95 IG2: 99 CG: 100	37% 49%	IG1:resistance IG2: behavioral	Core strengthening	12	3	20	Moderate to vigorous (60-80% 1RM)	S	Isometric dynamometry (trunk extensor MIF) Romberg test (COP displacement)
Korshøj et al. [47]	Cleaners	M (28), F (88)	45±9	Blue	IG: 57 CG: 59	51%	Endurance	Biking/running/aerobics	42	2	30	Moderate to vigorous (>60% VO_{2max})	S	Submaximal step test (VO2max*)
Mayer et al. [72]	Firefighters	M (87), F (9)	35±10	Blue	IG: 54 CG: 42	67%	Resistance	Core strengthening	12	2	10	low to vigorous	S	Biering-Sørensen (trunk muscle endurance time)
Mulla et al. [73]	Office worker	M(16), F(27)	44±10	White	IG: 21 CG: 22	76%	Resistance	Lower limb strengthening	12	3	45	Moderate to vigorous (OMNI 5-7)	S	Isometric dynamometry (knee extensor MIF)
Pedersen et al. [33]	Office workers	M (194), F (355)	45±9	White	IG1: 180 IG2: 187 CG: 182	45% 30%	IG1: Resistance IG2: Multicomponent	Trunk/shoulder strengthening Nordic walking/punching bags	52 52	3 3	20 20	Moderate to vigorous (10-15RM) NA	S S	Submaximal cycle ergometer (VO2max*) Isometric dynamometry (trunk extensor MIF)
Rodriguez-Hernandez and Wadsworth [61]	Office workers	M(16), F(52)	45±9	White	IG1: 24 IG2: 22 CG: 22	81%	IG1: Endurance IG2: Endurance	Intermittent walking Continuous walking	10 10	4 4	30 30	moderate (RPE 3-6)	L	Submaximal treadmill test (VO2peak)

Sertel et al. [29]	Industrial workers	F (68)	33±5	Blue	IG1: 23 IG2: 25 CG: 20	79%	IG1:Resistance IG2:Endurance	Elastic band strengthening Upper limb muscular endurance	8 8	3 3	30 30	Moderate to vigorous (50-85% MVC, 50-85% HRmax)	S S	Step test (VO2max*) Isometric dynamometry (hand grip MIF)
Strijk et al. [74]	Hospital employees;	M (179), F (551)	53±5	Blue	IG: 367 CG: 363	NA	Multicomponent	Yoga; whole-body strengthening; endurance; leisure time physical activity	24	1	45	Moderate to vigorous (65-90% HR)	S	Submaximal walking (VO2max*)
Vilela et al. [75]	Industrial workers	M (60)	25-35	Blue	IG: 30 CG: 30	NA	Multicomponent	Lower-/upper limb strengthening; soccer/volleyball/basketball	16	5	15	NA	S	Sit ups (trunk flexor muscle endurance)

1-RM one-repetition maximum; *CG* control group; *COP* center of pressure; *F* female; *HR* heart rate; *IG* intervention group; *M* male; *MIF* maximal isometric force; *MVC* maximum voluntary contraction; *NA* not applicable; *RM* repetition maximum; *RFD* rate of force development; *S* supervised; *L* less supervised; * VO2max estimated based on submaximal tests

Table 3: Physiotherapy Evidence Database (PEDro) score of the included randomized controlled trials.

Study	Eligibility criteria	Randomized allocation	Blinded allocation	Group homogeneity	Blinded subjects	Blinded therapists	Blinded assessor	Drop out <15 %	Intention-to-treat analysis	Between-group comparison	Point estimates and variability	PEDro score
Barene et al. [30, 31]	●	●	●	●	○	○	●	●	●	●	●	8
Brox and Frøystein [62]	●	●	○	●	○	○	●	○	●	●	●	6
Dalager et al. [22]	●	●	○	●	○	○	●	○	○	●	●	5
Dalager et al. [15, 32]	●	●	●	●	○	○	●	○	●	●	●	7
Genin et al. [66]	●	●	○	●	○	○	○	●	●	●	●	5
Gram et al. [34]	●	●	○	●	○	○	○	●	●	●	●	6
Granacher et al. [14]	●	●	○	●	○	○	○	●	○	●	●	5
Hamberg-van Reenen et al. [64]	●	●	●	●	○	○	○	●	●	●	●	7
Jørgensen et al. [65]	●	●	●	●	○	○	●	●	●	●	●	8
Korshøj et al. [47]	●	●	●	●	○	○	○	○	●	●	●	6
Mayer et al. [72]	●	●	○	●	○	○	●	●	●	●	●	7
Mulla et al. [73]	●	●	●	●	○	○	●	●	●	●	●	8
Pedersen [33]	●	●	○	○	○	○	●	○	●	●	●	5
Rodriguez-Hernandez and Wadsworth	●	●	○	●	○	○	○	○	●	●	●	5

[61]												
Sertel et al. [29]	●	●	○	●	○	○	○	○	○	●	●	4
Strijk et al. [74]	●	●	○	●	○	○	○	○	●	●	●	5
Vilela et al. [75]	●	●	●	●	○	○	○	○	○	●	●	5

● adds a point on the score, ○ adds no point on the score. The item “eligibility criteria” is not included in the final score.

Table 4: Overall effects of physical exercise training on measures of physical fitness as well as subgroup-specific effects for moderator variables.

	CRF			Muscle strength			Muscular endurance			Muscle power			Balance		
	SMD	S (I)	N	SMD	S (I)	N	SMD	S (I)	N	SMD	S (I)	N	SMD	S (I)	N
All	**0.34**	9 (12)	678	-0.04	11 (16)	816	**0.48**	4 (8)	292	**0.29**	3 (4)	125	0.35	3 (3)	139
Sex	P = 0.34			P = 0.53			P = NA			P = 0.92			P = NA		
Females	0.45	3 (4)	154	0.33	3 (3)	109	-			oEG			0.22	2 (2)	159
Males	oEG			oEG			oEG			-			-		
Mixed	**0.25**	5 (7)	489	-0.15	7 (12)	672	**0.50**	4 (7)	262	**0.40**	2 (3)	90	oEG		
Age	P = 0.02			P = 0.15			P = 0.57			P = 0.79			P = NA		
<45 years	**0.71**	4 (5)	326	0.26	6 (7)	354	**0.43**	3 (4)	148	0.36	1 (2)	73	-		
≥45 years	0.08	5 (7)	352	-0.29	5 (9)	462	**0.55**	1 (4)	144	0.43	2 (2)	52	0.35	3 (3)	139
Occupation	P = 0.97			P = 0.82			P = 0.04			P = 0.92			P = NA		
Blue collar	**0.35**	6 (7)	366	0.01	3 (3)	121	0.18	2 (2)	75	oEG			0.24	2 (2)	122
White collar	**0.36**	3 (5)	312	-0.06	8 (13)	695	**0.60**	2 (6)	217	**0.40**	2 (3)	90	oEG		

N total number of participants in the included experimental groups; *NA* not applicable; *oEG* only one experimental group; *S(I)* number of included studies (number of included experimental groups); *SMD* weighted mean standardised mean difference; bold values indicate significant effects

Table 5: Results of the multivariate random effects meta-regression analyses for program modalities of different categories to predict effects of physical exercise training conducted at the workplace on cardiorespiratory fitness.

Covariate	Coefficient	95% CI	Z-value	P-value
Intercept	-3.3447	-9.0654 to 2.3761	-1.15	0.2518
Period	-0.0224	-0.0528 to 0.008	-1.45	0.1481
Frequency	0.3941	-0.306 to 1.0941	1.1	0.2699
Duration	0.0324	-0.0219 to 0.0867	1.17	0.2417
Intensity	0.7714	-0.1889 to 1.7317	1.57	0.1154

Total number of interventions included in the model: *N* = 9. *CI* confidence interval;

Table 6: Overall effects of physical exercise training on measures of physical fitness as well as subgroup-specific effects for program modalities.

	CRF			Muscle strength			Muscular endurance			Muscle power			Balance		
	SMD	S (I)	N	SMD	S (I)	N	SMD	S (I)	N	SMD	S (I)	N	SMD	S (I)	N
All	0.34	9(12)	678	-0.04	11 (16)	816	0.48	4 (8)	292	0.29	3 (5)	162	0.35	3 (3)	139
Training type	P = 0.90			P = 0.72			P = 0.48			P = NA			P = NA		
Resistance	-			-0.20	6 (9)	356	0.44	2 (5)	189	-			-		
Endurance	0.36	5 (6)	202	-			-			-			-		
Team sports	oEG			oEG			-			oEG			oEG		
Multicomponent	0.36	4 (5)	439	0.14	5 (6)	476	0.58	2 (3)	103	0.40	2 (3)	90	0.31	2 (2)	104
Training period (weeks)	P < 0.001			P = 0.34			P =0.08			P = 0.88			P = NA		
≤8	oEG			0.51	3 (3)	49	-			oEG			oEG		
9-12	0.31	4 (5)	153	0.08	4 (4)	142	oEG			oEG			0.24	2 (2)	122
13-16	-			-			oEG			-			-		
17-20	0.74	1 (2)	73	-0.02	2 (6)	219	0.60	2 (6)	217	0.36	1 (2)	73	-		
21-24	0.07	2 (2)	177	-			-			-			-		
>24	0.10	2 (2)	250	-0.82	2 (3)	406	-			-			-		
Frequency (x/week)	P = 0.49			P = 0.42			P = 0.65			P = NA			P = NA		
≤1	0.18	4 (4)	405	-0.97	3 (3)	334	oEG			-			-		
2	0.36	3 (5)	202	0.14	3 (4)	117	0.47	2 (3)	118	0.36	2 (3)	108	oEG		
3	0.61	2 (3)	71	0.24	6 (7)	311	0.39	2 (2)	72	-			oEG		
≥4	-			-0.11	2 (2)	54	0.50	2 (2)	67	oEG			oEG		
Session duration (min)	P = 0.42			P = 0.37			P = 0.29			P = NA			P = NA		
≤15	-			-0.03	3 (3)	89	0.33	3 (3)	112	oEG			oEG		
16-30	0.47	4 (5)	163	0.25	4 (5)	255	0.39	1 (2)	72	-			oEG		

31-45	0.44	2 (3)	211	0.25	2 (3)	94	**0.72**	1(2)	73	0.36	1 (2)	73	-		
46-60	**0.17**	3 (4)	304	-0.57	5 (5)	378	oEG			oEG			oEG		
Intensity	P = 0.83			P = NA			P = NA			P = NA			P = NA		
Low to vigorous	0.24	1 (2)	72	oEG			oEG			0.17	1 (2)	72	oEG		
Moderate	0.17	1 (2)	46	oEG			-			oEG			oEG		
Moderate to vigorous	0.34	5 (5)	448	-0.15	8 (11)	584	**0.55**	1 (4)	144	-			oEG		
Supervision	P = 0.40			P = 0.35			P = NA			P = 0.79			P = NA		
Supervised	**0.38**	8 (10)	632	-0.10	8 (12)	726	**0.51**	4 (7)	264	0.36	1(2)	73	oEG		
Less supervised	0.17	1 (2)	46	0.19	3 (3)	81	oEG			**0.43**	2 (2)	52	**0.58**	2 (2)	52

N total number of participants in the included experimental groups; *NA* not applicable; *oEG* only one experimental group; *S(I)* number of included studies (number of included experimental groups); *SMD* weighted mean standardised mean difference; *y* years; bold values indicate significant effects

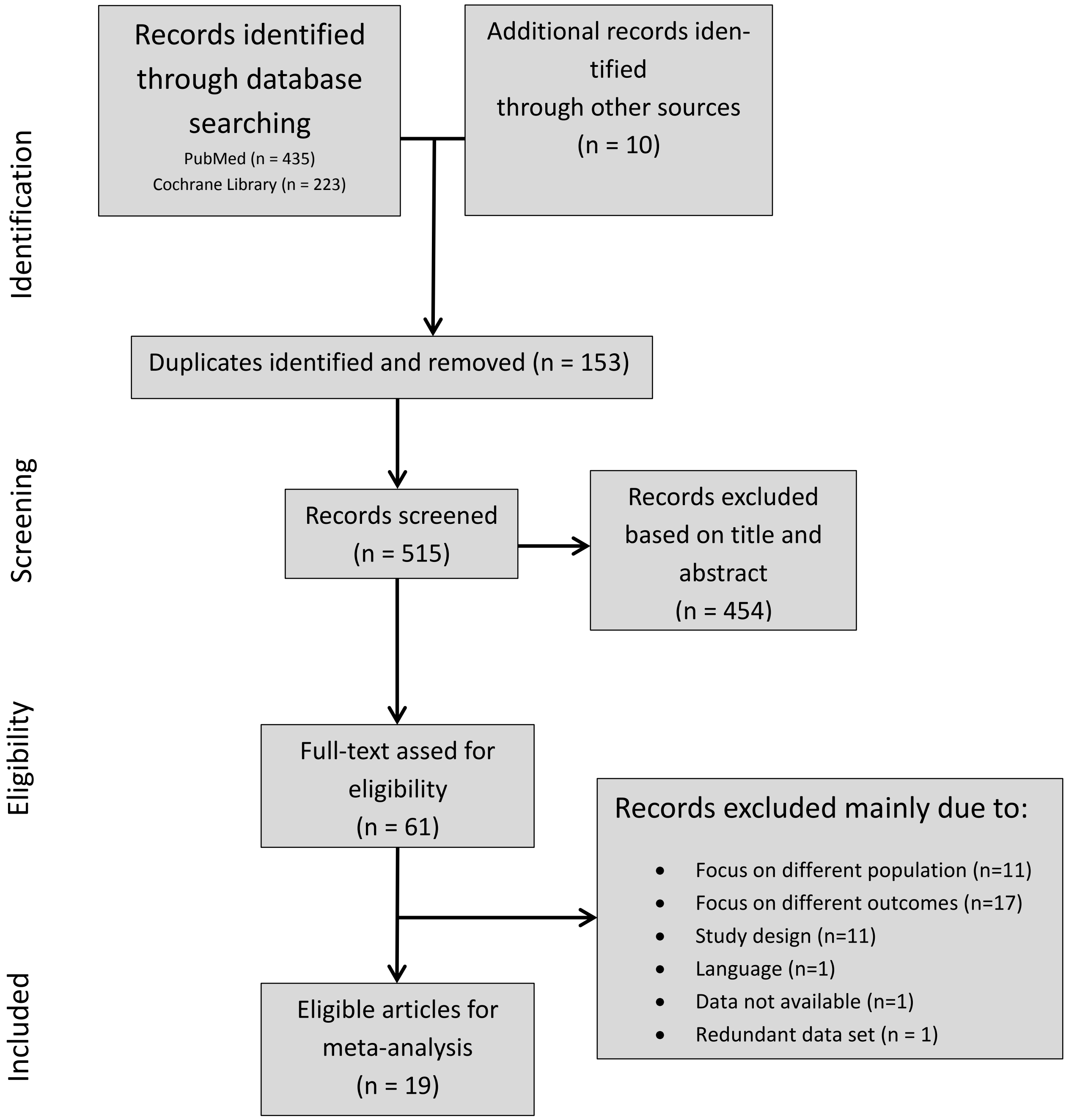
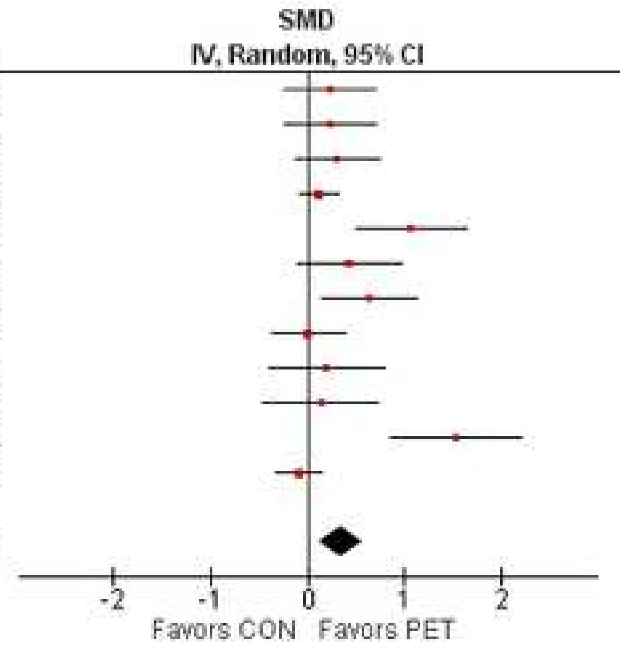

Identification
Screening
Eligibility
Included
Records identified through database searching
PubMed (n = 435)
Cochrane Library (n = 223)
Additional records iden-tified through other sources (n = 10)
Duplicates identified and removed (n = 153)
Records screened (n = 515)
Records excluded based on title and abstract (n = 454)
Full-text assed for eligibility (n = 61)
Records excluded mainly due to:
Focus on different population (n=11)
Focus on different outcomes (n=17)
Study design (n=11)
Language (n=1)
Data not available (n=1)
Redundant data set (n = 1)
Eligible articles for meta-analysis (n = 19)

Figure 2

Study or Subgroup	SMD	SE	PET Total	CON Total	Weight	SMD IV, Random, 95% CI
Barene et al. [30] (IG 1)	0.24	0.24	37	35	8.2%	0.24 [-0.23, 0.71]
Barene et al. [30] (IG 2)	0.24	0.24	35	35	8.2%	0.24 [-0.23, 0.71]
Brox and Frøystein [62]	0.31	0.22	39	42	8.7%	0.31 [-0.12, 0.74]
Dalager et al. [15]	0.12	0.1	193	194	12.1%	0.12 [-0.08, 0.32]
Genin et al. [66] (IG 1)	1.07	0.29	36	22	7.0%	1.07 [0.50, 1.64]
Genin et al. [66] (IG 2)	0.43	0.27	37	22	7.4%	0.43 [-0.10, 0.96]
Gram et al. [34]	0.64	0.25	35	32	7.9%	0.64 [0.15, 1.13]
Korshøj et al. [47]	0.01	0.19	57	59	9.6%	0.01 [-0.36, 0.38]
Rodriguez-Hernandez and Wadsworth [61] (IG1)	0.2	0.3	24	22	6.7%	0.20 [-0.39, 0.79]
Rodriguez-Hernandez and Wadsworth [61] (IG2)	0.14	0.3	22	22	6.7%	0.14 [-0.45, 0.73]
Sertel et al. [29] (IG 2)	1.53	0.34	25	20	5.9%	1.53 [0.86, 2.20]
Strijk et al. [74]	-0.08	0.12	138	122	11.6%	-0.08 [-0.32, 0.16]
Total (95% CI)			**678**	**627**	**100.0%**	**0.34 [0.13, 0.56]**

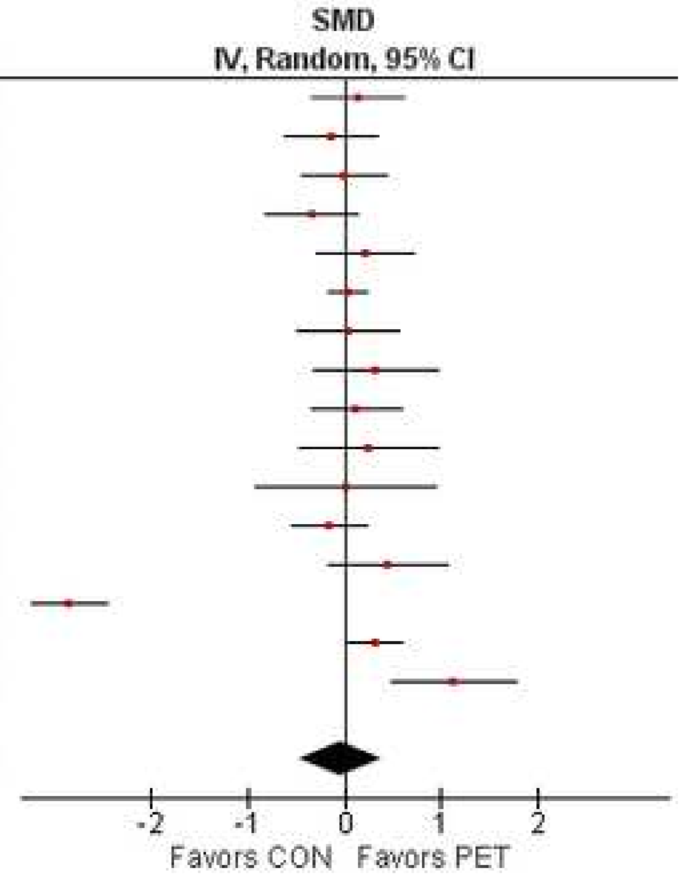
Heterogeneity: $Tau^2 = 0.09$; $Chi^2 = 35.54$, df = 11 (P = 0.0002); $I^2 = 69\%$

Test for overall effect: Z = 3.11 (P = 0.002)



Study or Subgroup	SMD	SE	PET Total	CON Total	Weight	SMD IV, Random, 95% CI
Barene et al. [31] (IG 1)	0.14	0.24	35	35	6.4%	0.14 [-0.33, 0.61]
Dalager et al. [22] (IG 1)	-0.14	0.24	35	33	6.4%	-0.14 [-0.61, 0.33]
Dalager et al. [22] (IG 2)	0	0.23	45	33	6.4%	0.00 [-0.45, 0.45]
Dalager et al. [22] (IG 3)	-0.34	0.24	37	33	6.4%	-0.34 [-0.81, 0.13]
Dalager et al. [22] (IG 4)	0.21	0.26	29	33	6.3%	0.21 [-0.30, 0.72]
Dalager et al. [32]	0.04	0.1	193	194	6.8%	0.04 [-0.16, 0.24]
Genin et al. [66] (IG 1)	0.04	0.27	36	22	6.2%	0.04 [-0.49, 0.57]
Genin et al. [66] (IG 2)	0.33	0.33	37	22	5.9%	0.33 [-0.32, 0.98]
Gram et al. [34]	0.12	0.24	35	32	6.4%	0.12 [-0.35, 0.59]
Granacher et al. [14]	0.25	0.36	17	15	5.8%	0.25 [-0.46, 0.96]
Hamberg-van Reenen et al. [64]	0.01	0.47	9	9	5.2%	0.01 [-0.91, 0.93]
Jørgensen et al. [65] (IG 1)	-0.15	0.2	51	51	6.5%	-0.15 [-0.54, 0.24]
Mulla et al. [73]	0.45	0.31	21	22	6.0%	0.45 [-0.16, 1.06]
Pedersen et al. [33] (IG 1)	-2.83	0.2	106	106	6.5%	-2.83 [-3.22, -2.44]
Pedersen et al. [33] (IG 2)	0.31	0.14	107	106	6.7%	0.31 [0.04, 0.58]
Sertel et al. [29] (IG 1)	1.13	0.33	23	20	5.9%	1.13 [0.48, 1.78]
Total (95% CI)			**816**	**766**	**100.0%**	**-0.04 [-0.46, 0.38]**

Heterogeneity: $Tau^2 = 0.66$; $Chi^2 = 221.40$, df = 15 ($P < 0.00001$); $I^2 = 93\%$
Test for overall effect: $Z = 0.19$ ($P = 0.85$)



Study or Subgroup	SMD	SE	PET Total	CON Total	Weight	SMD IV, Random, 95% CI
Dalager et al. [22] (IG 1)	0.78	0.25	35	32	12.8%	0.78 [0.29, 1.27]
Dalager et al. [22] (IG 2)	0.48	0.24	44	32	13.7%	0.48 [0.01, 0.95]
Dalager et al. [22] (IG 3)	0.64	0.25	37	32	12.8%	0.64 [0.15, 1.13]
Dalager et al. [22] (IG 4)	0.29	0.26	28	32	11.9%	0.29 [-0.22, 0.80]
Genin et al. [66] (IG 1)	0.77	0.28	36	22	10.4%	0.77 [0.22, 1.32]
Genin et al. [66] (IG 2)	0.67	0.28	37	22	10.4%	0.67 [0.12, 1.22]
Mayer et al. [72]	0.06	0.22	45	38	16.0%	0.06 [-0.37, 0.49]
Vilela et al. [75]	0.35	0.26	30	30	11.9%	0.35 [-0.16, 0.86]
Total (95% CI)			**292**	**240**	**100.0%**	**0.48 [0.30, 0.67]**

Heterogeneity: Tau² = 0.01; Chi² = 7.81, df = 7 (P = 0.35); I² = 10%
Test for overall effect: Z = 5.11 (P < 0.00001)

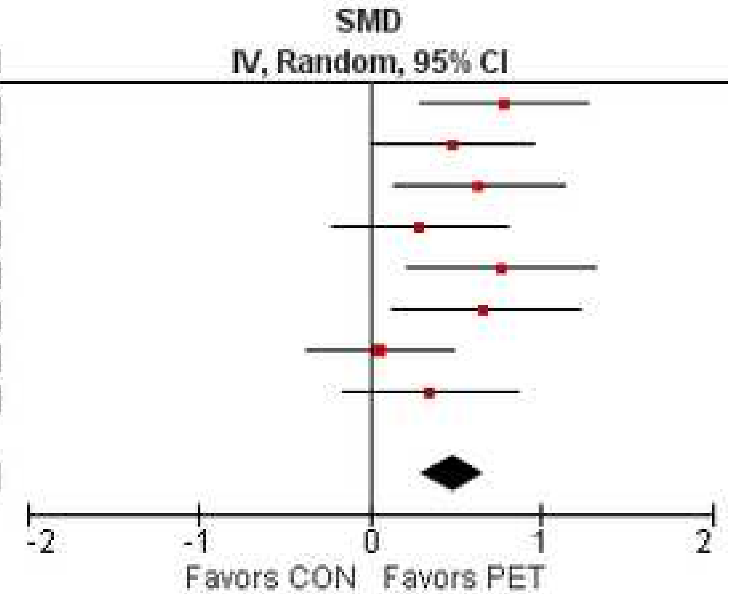
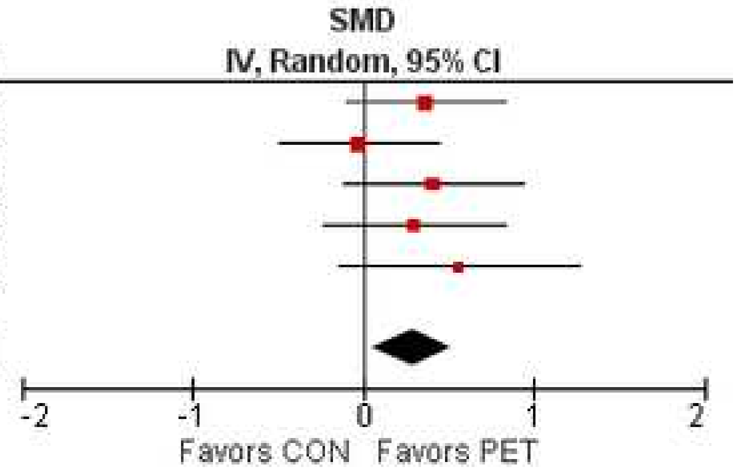


Figure 5

Study or Subgroup	SMD	SE	PET Total	CON Total	Weight	SMD IV, Random, 95% CI
Barene et al. [31] (IG 1)	0.37	0.24	35	35	24.8%	0.37 [-0.10, 0.84]
Barene et al. [31] (IG 2)	-0.02	0.24	37	35	24.8%	-0.02 [-0.49, 0.45]
Genin et al. [66] (IG 1)	0.41	0.27	36	22	19.6%	0.41 [-0.12, 0.94]
Genin et al. [66] (IG 2)	0.3	0.27	37	22	19.6%	0.30 [-0.23, 0.83]
Granacher et al. [14]	0.56	0.36	17	15	11.0%	0.56 [-0.15, 1.27]
Total (95% CI)			**162**	**129**	**100.0%**	**0.29 [0.05, 0.52]**

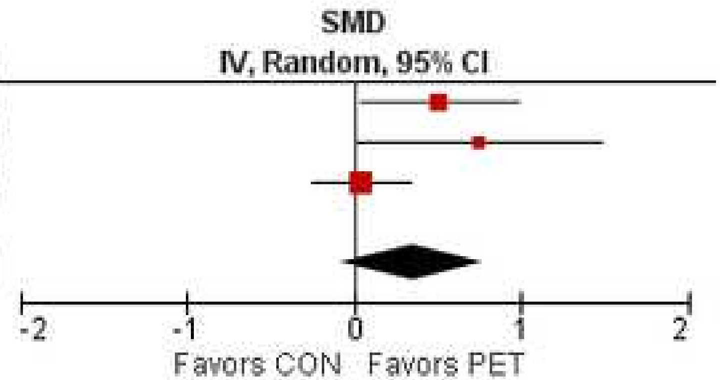
Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 2.54$, df = 4 (P = 0.64); $I^2 = 0\%$

Test for overall effect: Z = 2.41 (P = 0.02)



Study or Subgroup	SMD	SE	PET Total	CON Total	Weight	SMD IV, Random, 95% CI
Barene et al. [31] (IG 1)	0.51	0.24	35	35	33.6%	0.51 [0.04, 0.98]
Granacher et al. [14]	0.75	0.37	17	15	21.5%	0.75 [0.02, 1.48]
Jørgensen et al. [65] (IG 1)	0.04	0.15	87	85	44.8%	0.04 [-0.25, 0.33]
Total (95% CI)			**139**	**135**	**100.0%**	**0.35 [-0.08, 0.78]**

Heterogeneity: $Tau^2 = 0.08$; $Chi^2 = 4.94$, df = 2 (P = 0.08); $I^2 = 60\%$
Test for overall effect: Z = 1.61 (P = 0.11)



SUPPLEMENTS

Table S1: Search terms of the systematic literature review included in a Boolean search strategy.

Population	(worker* OR working place OR worksite OR work site OR workplace OR work-place OR workforce OR work-related OR “work environment” OR employee* OR labor OR labour OR occupational OR occupation OR company OR business OR industry OR industrial) NOT (patient* OR disease* OR disorder* OR stroke OR Parkinson OR children OR young* OR youth OR adolescents) AND
Intervention	(physical OR cardio OR aerobic OR endurance OR interval OR high-intensity OR resistance OR strength OR weight OR functional OR core OR muscle OR stretching OR multicomponent OR combined OR concurrent) AND (training OR exercise OR exercises OR intervention OR activity OR program OR programme OR application) AND
Outcomes	performance OR fitness OR strength OR force OR torque OR muscular OR endurance OR aerobic OR anaerobic OR exertion OR ergometer OR wingate OR run OR running OR RPE OR recovery OR power OR explosive OR ergonomic OR balance OR stance OR walk OR posture OR “postural control” OR flexibility OR “range of motion” OR pliability AND
Study design/ Comparator	"controlled trial" OR "controlled design" OR "controlled study" OR "controlled intervention" OR "control group" OR "control groups" OR "intervention group"

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Journal name: Sports Medicine Corresponding author: Olaf Prieske

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Fees for participation in review activities such as data monitoring boards, etc	X		
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Royalties	X		
Other (err on the side of full disclosure)	X		

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